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# **In-Service Evaluation of HVOF Coated Main Landing Gear on Navy P-3 Aircraft**

**Jon L. Devereaux**

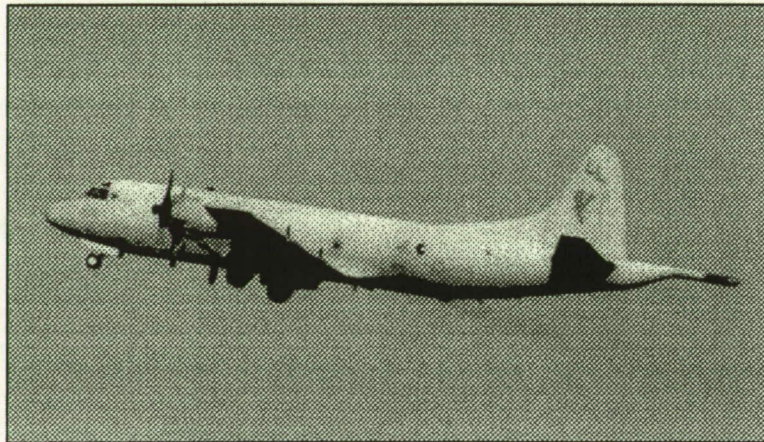
**Structural Materials Engineer, NASA, Kennedy Space Center, Florida, USA**

[Jon.Devereaux@nasa.gov](mailto:Jon.Devereaux@nasa.gov)

**Clint Forrest**

**Landing Gear Systems Engineer, ES-3 Inc, Clearfield, Utah, USA**

[Clint.Forrest@es3inc.com](mailto:Clint.Forrest@es3inc.com)



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## **ABSTRACT**

Due to the environmental and health concerns with Electroplated Hard Chrome (EHC), the Hard Chrome Alternatives Team (HCAT) has been working to provide an alternative wear coating for EHC. The US Navy selected Tungsten-Carbide Cobalt (WC-17Co) High Velocity Oxy-Fuel (HVOF) thermal spray coating for this purpose and completed service evaluations on select aircraft components to support the HCAT charter in identifying an alternative wear coating for chrome plating. Other benefits of WC-Co thermal spray coatings over EHC are enhanced corrosion resistance, improved durability, and exceptional wear properties.

As part of the HCAT charter and to evaluate HVOF coatings on operational Navy components, the P-3 aircraft was selected for a service evaluation to determine the coating durability as compared to chrome plating. In April 1999, a VP-30 P-3 aircraft was outfitted with a right-hand Main Landing Gear (MLG) shock strut coated with WC-Co HVOF thermal spray applied to the piston barrel and four axle journals. The HVOF coating on the piston barrel and axle journals was applied by Southwest United Industries, Inc. This HVOF coated strut assembly has since completed 6,378 landings.

Teardown analysis for this WC-Co HVOF coated MLG asset is significant in assessing the durability of this wear coating in service relative to EHC and to substantiate Life Cycle Cost (LCC) data to support a retrograde transition from EHC to HVOF thermal spray coatings.

Findings from this teardown analysis may also benefit future transitions to HVOF thermal spray coatings by identifying enhancements to finishing techniques, mating bearing and liner material improvements, improved seal materials, and improvements in HVOF coating selection.

## **1. INTRODUCTION**

The P-3 HVOF service evaluation asset was installed on two different VP-30 aircraft during the 7 year period from April 1999 to January 2006. It was removed from the initial aircraft and repaired at NADEP JAX for an internal strut leak at ID-2 not related to the HVOF coating. The repaired HVOF coated shock strut assembly was then returned to VP-30 and installed on a second aircraft to complete the service evaluation.

The service evaluation was performed on a noninterference basis with the Squadron in which the number of landings was tracked and key findings monitored by NADEP JAX. The HVOF coated strut was removed from service on 15 January 2006 due to a mandatory aircraft service bulletin (AFB 383) and returned to supply for normal Phased Depot Maintenance (PDM). Heroux-Devtek is the source of repair for the P-3 MLG shock strut and agreed to participate in a teardown analysis to support the US Navy and the HCAT charter.

## **2. INITIAL INSPECTION**

The P-3 R/H MLG shock strut assembly was examined in the as-received condition. The strut showed no visible signs of leakage, damage or other issues that would have forced it off the aircraft for cause. Figure 1 shows the disassembled strut assembly.



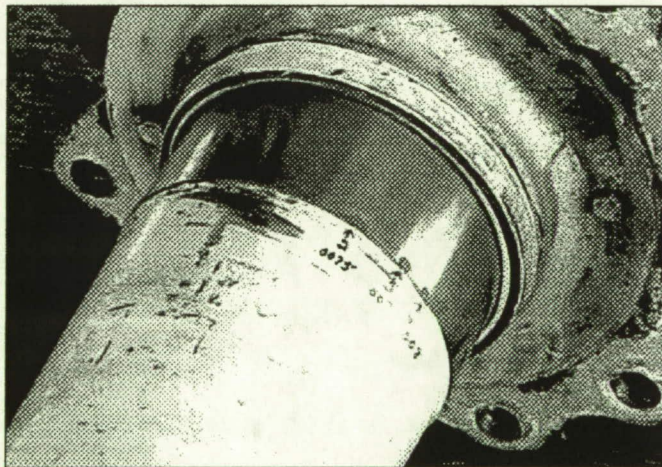


**Figure 1. P-3 MLG Shock Strut Disassembled**

### **3. FINDINGS**

#### **3.1 HVOF COATED AXLE JOURNAL VISUAL INSPECTION**

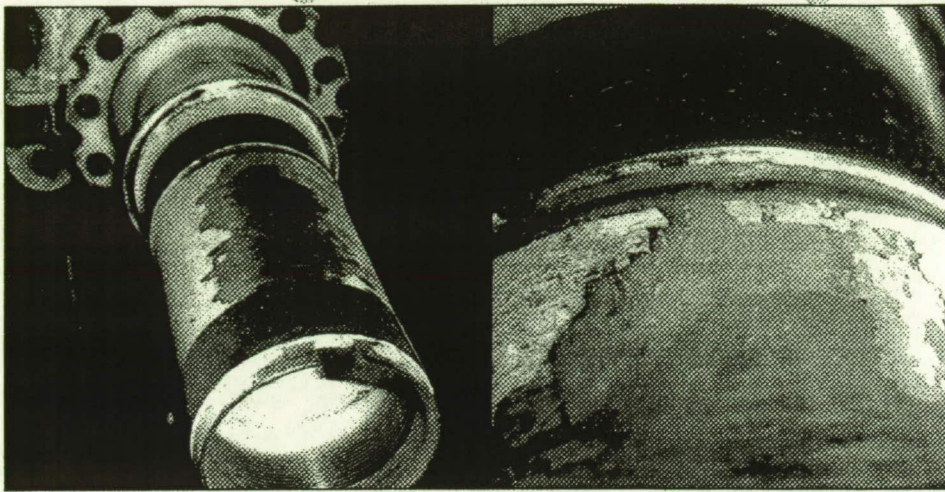
The service evaluation was an excellent test for a known problem of coating chipping/flaking at the edge of the axle wheel bearing journals. Typically EHC on axle journals of military aircraft is chipped as shown in Figure 2 when the brake assembly is installed and dragged across the axle journals without the use of a brake dolly.



**Figure 2. Typical Brake Install Chrome Damage on Axle Journals**

The HVOF axle journal inspection indicated the brakes had been repeatedly dragged over the journal edges as evidenced by the damaged paint on the top of the axle surface shown below in Figure 3.





**Figure 3. HVOF Piston Axle Brake Install Damage Between Axle Journals**

The four HVOF coated axle journals were all in very good condition and still showed staining evidence from the plastic mesh used to protect the axles during original processing indicating essentially no wear to the HVOF surface. There was no chipping of the HVOF coating edges (as typically seen with chrome plating).

### **3.2 HVOF Inspection**

The following inspections were performed, and resulted in no significant findings:

- **HVOF Piston Barrel Visual and FPI Inspection**
- **HVOF Strut Axle Journal Visual and FPI Inspection**
- **HVOF Piston Barrel and Axle Journal Surface Roughness Inspection**
- **HVOF Piston Barrel and Axle Journal Dimensional Inspection**

### **3.3 Lower Bearing Dimensional Inspection**

Coordinate Measuring Machine (CMM) inspection of the lower bearing showed normal concentricity. The bearing exhibited significant wear in both the OD and ID, with a total overall wear of 0.049 inches.

### **3.4 Shock Strut Fluid Analysis**

The hydraulic fluid was captured from this service evaluation strut in two separate containers. The initial drain of the strut fluid from the top of the cylinder was very clean. The internal lower chamber hydraulic fluid was more indicative of a strut with a long service life and was very dark in appearance. Analysis of both samples verified that the fluid was the correct type. The lower chamber fluid also contained trace elements of Al, Ca, Cr, Cu, Fe, Mg, Mo and Zn, believed to be wear particles from service.

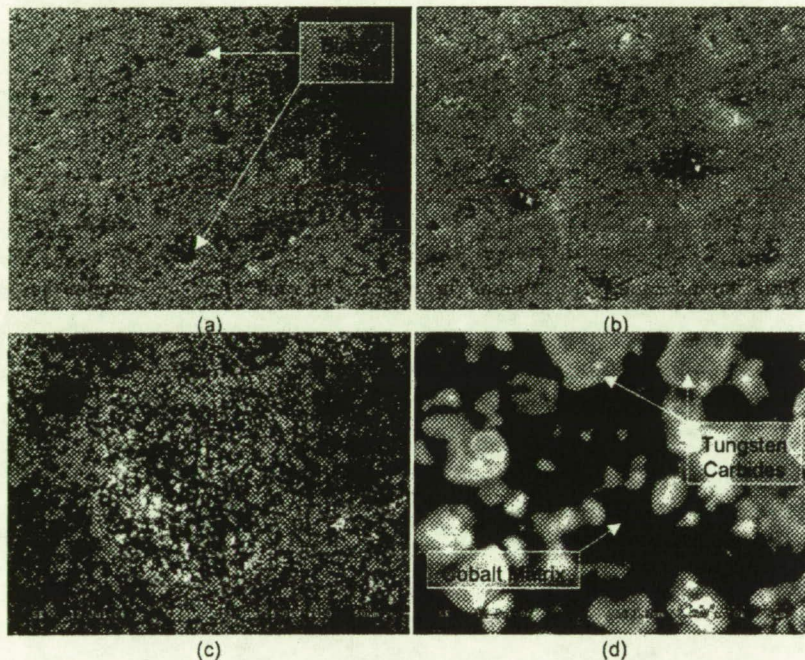
### **3.5 Shock Strut Seal Analysis**

Analysis indicated that the seals and scraper were in good condition. There was no evidence that the surface roughness at the lower barrel section further degraded the seals



### 3.6 HVOF Coating Microscopic Analysis

Visual and surface roughness inspection revealed the lower portion of the shock strut barrel had degraded from its original condition. This degradation was observed as "black spots" on the surface as shown in Figure 4. Due to the fact the piston had to be condemned for exceeding the minimum wall thickness requirement due to corrosion (not related to the HVOF coated surfaces), the piston was available for destructive microscopic analysis. Three separate coupons were sectioned from each area of the piston for microscopic analysis using a Scanning Electron Microscope (SEM) with Energy Dispersive Spectroscopy (EDS). SEM analysis revealed that the "black spots" were shallow pits, containing corrosion byproducts, shown below in Figure 4. Elements detected by EDS in the pitted areas included Cl, K, Ca, and Na, indicating that the pitting was likely the result of seawater environmental attack of the cobalt matrix.



**Figure 4. Secondary Electron Images of Black Spots (Pits) on Piston Barrel Lower Environmentally Exposed Surface: (a) x40, (b) x120, (c) x800 and (d) x7000**

Metallographic analysis of polished cross sections indicated that the worst pits were approximately 0.001 inches in depth and 0.010 inches in diameter, which is considered larger and deeper than average porosity of the HVOF coating surface.

### 4. SUMMARY

Based upon the findings of this report, it is concluded that the HVOF coated piston performed a satisfactory service history in landings equivalent to the component life for most land-based military aircraft such as fighters and patrol aircraft without incident.

Although the piston was condemned for another reason, it is believed the barrel section could have been superfinished to remove black spot pitting and phenolic bearing material transfer, restoring all the dimensional and surface roughness requirements and returned to service for another maintenance cycle.